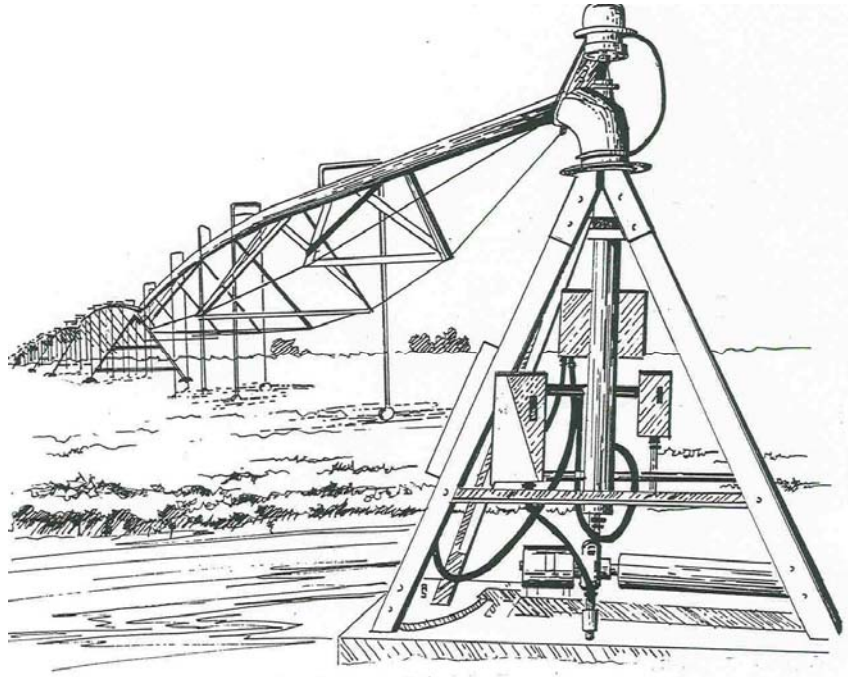


Wastewater Land Application Operators Study and Reference Manual



**Idaho Department of Environmental Quality
and
Wastewater Land Application Exam & Training
Development Committee**



October 2005

This page intentionally left blank for correct double-sided printing.

Wastewater Land Application Operators Study and Reference Manual

**Idaho Department of Environmental Quality
and
Wastewater Land Application Exam & Training
Development Committee**

October 2005

This page intentionally left blank for correct double-sided printing.

Acknowledgements

The Wastewater Land Application Permit Program and the wastewater treatment and collection system requirements for licensed operators are administered by the Idaho Department of Environmental Quality. Individuals who operate wastewater land application systems are required to hold two licenses: a wastewater treatment license and a wastewater land application license. The Idaho Bureau of Occupational Licensing administers the testing and licensing of individual wastewater operators.

This manual is a combination of guidance materials gathered from various technical resources, with input and expertise from the Idaho Department of Environmental Quality wastewater engineering and technical staff.

Special thanks are extended to the North Carolina Department of Environment and Natural Resources for allowing the use of their *Spray Irrigation Systems Operators Training Manual* as an immensely valuable starting point in the production of this manual.

Very special thanks go to Larry Waters, Department of Environmental Quality and Claudia Gaeddert, CLPE Consulting Engineers—both Wastewater Land Application Exam and Training Development Committee members—who were the primary authors of this study and reference manual.

This page intentionally left blank for correct double-sided printing.

Table of Contents

Acknowledgements	V
Introduction	xvii
Purpose of This Manual	xvii
This Manual and the Law	xvii
How This Manual Was Developed	xviii
Updates to This Manual	xviii
State of Idaho WLAP Operator Certification Needs-to-Know Criteria ..	xix
Section 1: Wastewater Characteristics and Loading Fundamentals	xix
Section 2: Soils & Agronomy	xix
Section 3: Ground water & Hydrology	xx
Section 4: Wastewater Disinfection & Buffer Zones	xxi
Section 5: Storage Lagoons	xxi
Section 6: Distribution Network & Devices	xxii
Section 7: Irrigation System Operations & Scheduling	xxii
Section 8: Sampling	xxiii
Section 9: Site Operations & Maintenance	xxiii
Section 10: Calculations	xxiv
Section 11: Health and Safety	xxv
Section 12: Idaho Rules & Requirements	xxv
1. Wastewater Characteristics and Loading Fundamentals	1-1
1.1 Sources of Wastewater	1-1
1.2 Types of Wastewater	1-2
1.3 Wastewater Physical Characteristics	1-2
Color	1-2
Odor	1-2
Temperature	1-3
Solids	1-3
1.4 Other Important Wastewater Characteristics	1-5
Pathogenic Organisms	1-5
Biochemical Oxygen Demand	1-6
Dissolved Oxygen	1-6
Nutrients	1-7
Metals	1-8
Persistent Organic Chemicals	1-9
pH	1-9
Salts	1-10

TABLE OF CONTENTS

1.5	Municipal Reclaimed Wastewater Effluent Classes	1-10
1.6	Hydraulic and Constituent Loading Rates	1-12
	Hydraulic Loading Rate	1-12
	Constituent Loading Rates	1-13
	Land Limiting Constituent	1-14
	References:	1-14
2.	Soils & Agronomy	2-1
2.1	Soil Components and Profiles	2-1
	Soil Components	2-1
	Soil Profiles	2-2
2.2	Soil Physical Characteristics	2-4
	Soil Texture	2-4
	Soil Structure	2-9
	Organic Material Contents	2-11
	Soil Depth	2-11
	Soil Color	2-11
	Soil Drainage/Wetness	2-12
	Topography and Landscape Position	2-13
2.3	Soil Chemical Characteristics.....	2-14
	Texture and Organic Matter Content	2-15
	Cation Exchange Capacity	2-15
	Sodium Adsorption Ratio (SAR)	2-17
	pH	2-17
2.4	Soil Moisture.....	2-17
	Plant Available Water Content	2-18
	Infiltration	2-20
	Permeability	2-20
2.5	Treatment of Wastewater	2-21
	Physical Treatment	2-21
	Chemical Treatment	2-21
	Biological Treatment	2-22
2.6	Fate of Waste Constituents	2-22
2.7	Agronomy	2-24
	Essential Nutrients	2-24
	Nutrient Availability and Nutrient Management	2-25
2.8	Crop Nutrient Requirements.....	2-32
	References:	2-32
3.	Ground Water & Hydrology	3-1
3.1	The Hydrologic Cycle	3-1
3.2	Evaporation and Evapotranspiration	3-2
3.3	Runoff to Surface Waters	3-4
	Soil Erosion	3-4
	Surface Water Pollution	3-5

TABLE OF CONTENTS

	Ponding	3-5
3.4	Infiltration into the Soil	3-5
	Soil Water	3-5
	Water Table Depths	3-6
	Artificially Affecting Site Hydrology	3-8
	Ground Water Monitoring Wells	3-9
3.5	Summary	3-12
	References:	3-12
4.	Wastewater Disinfection & Buffer Zones	4-1
4.1	Disinfection	4-1
	Chlorination	4-1
	Leak Detection and Chlorine Safety	4-5
	Ultraviolet Radiation	4-6
	Ozone Disinfection	4-6
4.2	Buffer Zones	4-7
	References:	4-9
5.	Storage Lagoons	5-1
5.1	Lagoon Design and Configuration	5-1
5.2	Lagoon Operation and Maintenance	5-3
	Vegetation	5-3
	Erosion	5-4
	Excessive Algae	5-4
	Odor Prevention	5-5
	Insufficient Freeboard	5-6
	Short-Circuiting	5-6
	References:	5-7
6.	Distribution Network & Devices	6-1
6.1	Pumps and Controls	6-1
	General Concepts	6-1
	Pumps	6-5
	Pumping System Components	6-6
	Priming a Pump	6-8
	Cavitation	6-8
	Water Hammer	6-9
	Pump Controls	6-9
	Water Level Sensing and Pump Control	6-9
	Alarms	6-10
	Counters	6-10
	Telemetry	6-10
	Microprocessors	6-10
	Meters	6-10
6.2	Distribution Network and Devices	6-11
	Pipes, Fittings, Connections, and Valves	6-11

TABLE OF CONTENTS

Irrigation Application Devices (Sprinklers)	6-16
Solid Set Irrigation Equipment	6-17
Mobile Irrigation Equipment	6-19
Operational Issues	6-22
References:	6-24
7. Irrigation Systems Operations & Scheduling	7-1
7.1 Irrigation Scheduling.....	7-2
Determining When to Irrigate	7-2
Basic Soil-Water Relationships	7-3
Estimating Soil-Water Content	7-4
7.2 Determining How Much to Irrigate	7-16
Operational Considerations	7-19
Determination of Irrigation Rate for Stationary Sprinklers	7-21
Center Pivot Systems	7-22
7.3 System Calibration	7-22
Summary of Irrigation Scheduling	7-23
References:	7-24
8. Sampling	8-1
8.1 Soil Sampling	8-1
How Can a Soil Test Be Used to Determine the Land Limiting Nutrient?	8-2
8.2 Plant Tissue Sampling.....	8-2
Taking a Representative Sample	8-3
Selecting the Best Indicator Sample for Crop Management	8-3
Choosing Sample Size	8-3
Submitting the Sample	8-4
8.3 Wastewater Sampling	8-4
Wastewater Sampling Terminology	8-5
Sampling Procedures	8-6
8.4 Ground water Sampling.....	8-6
8.5 Equipment and Supplies	8-7
8.6 Minimizing Contamination Risks	8-8
8.7 Measuring Static Water Level and Calculating Well Volume.....	8-9
8.8 Purging the Well	8-10
Purging with a Pump	8-10
Purging with a Bailer	8-11
8.9 Collecting Samples.....	8-11
Sampling with a Portable Pump	8-11
Sampling with a Bailer	8-11

TABLE OF CONTENTS

8.10	Minimum Cleaning Techniques	8-12
8.11	Special Handling Procedures	8-12
8.12	Filtering Samples	8-13
8.13	General Procedures for Packing Ground Water Samples	8-13
9.	Site Operations and Maintenance	9-1
9.1	Soil Management.....	9-2
	Ponding, Runoff, Surfacing, or Prolonged Saturation	9-3
	Wastewater Mounding	9-4
	Surface Crusting	9-5
	Compaction	9-6
	Excess Wastewater Constituents	9-6
9.2	Crop Management	9-11
	Crop Selection	9-13
	Nutrient and Physical Management	9-15
	Pest Control	9-16
	Best Management Practices	9-17
	Troubleshooting	9-21
9.3	Management of Wastewater Application	9-23
	Uniformity of Wastewater Distribution	9-23
	Winter Operation	9-24
9.4	Management of System Components	9-25
	Land Application Equipment	9-25
	Drainage Systems	9-28
	Soil and Site Components	9-30
	Operation and Maintenance Manual	9-30
	Records	9-31
9.5	Environmental Protection.....	9-32
	Emergency Action Plans	9-33
	References:	9-36
10.	Calculations	10-1
10.1	Include Units of Measurement.....	10-1
10.2	Types of Calculations	10-1
	Concentration and Constituent Loading Rate Calculations	10-2
	Hydraulic Loading Rate Calculations	10-4
	Plant Available Nitrogen Calculations	10-10
	Sodium Adsorption Ratio Calculations	10-11
	Wastewater Application Rate Calculations	10-13
	Crop Yield and Crop Uptake Calculations	10-15
	References:	10-16
11.	Health and Safety	11-1
11.1	Regulatory Overview	11-1
	Employer Responsibilities	11-1
	Site Supervisor Responsibilities	11-1

TABLE OF CONTENTS

	Employee Responsibilities	11-2
11.2	Health and Safety Program	11-2
	Incident Reporting	11-2
	Hazard Communication Standard	11-3
	Chemical Hygiene Plan	11-3
	Personal Protective Equipment	11-3
11.3	Health and Safety Hazards	11-11
	Health and Safety Measures	11-12
	OSHA Process Safety Management and EPA Risk Management Programs	11-12
11.4	Confined Space Safety	11-13
11.5	General Site Safety	11-14
	Lockout/Tagout Policy	11-15
	Electrical Safety	11-16
	Mechanical Safety	11-16
11.6	Land Application Site Vehicle Use	11-19
	Heavy Off-The-Road Vehicle Operation	11-19
11.7	Lagoon Safety	11-19
11.8	Fire Prevention and Protection	11-20
11.9	Medical Safety	11-20
	First Aid Training	11-20
	Blood-borne Pathogen Awareness	11-21
	Eyewash Stations	11-21
	Immunization	11-22
	Personal Hygiene	11-22
	Safe Lifting and Carrying Techniques	11-22
11.10	Public Health and Safety	11-23
	References:.....	11-23
12.	Idaho Rules and Requirements.....	12-1
12.1	Wastewater-Land Application Permit Rules (IDAPA 58.01.17)	12-2
	Application Process	12-2
	Plans and Specification Review	12-3
	Permit Renewals	12-4
	Entry and Access	12-4
	Monitoring and Reporting Requirements	12-4
	Permit Requirements	12-5
	Permit Revocation	12-7
	Penalties for Permit Violations	12-7
	Waivers	12-7
	Backflow Prevention Assemblies	12-7
	Class A Operator Requirements	12-8
	Class A Treatment Requirements	12-8
	Class A Effluent Identification	12-10
	Rapid infiltration systems	12-12

TABLE OF CONTENTS

12.2	Ground Water Quality Rule (IDAPA 58.01.11)	12-12
	Numerical Ground Water Standards	12-12
	Ground Water Monitoring	12-13
12.3	Water Quality Standards and Wastewater Treatment Requirements (IDAPA 58.01.02).....	12-13
	Designation and Responsibilities of the Responsible Charge Operator	12-14
	Responsibilities of a Substitute Responsible Charge Operator	12-15
	Responsibilities of Contract Operators	12-15
	License Requirements Exclusive to Wastewater-Land Application Operators	12-15
12.4	Rules of the Board of Drinking Water and Wastewater Professionals (IDAPA 24.05.01).....	12-15
	Licensure of Wastewater Land Application Operators	12-16
	Responsibilities of Certified Operators	12-16
	Disciplinary Actions	12-17
12.5	Other Regulations.....	12-17
	References:	12-18
A	Appendix A: Monitoring Well Construction Guidance	A-1
B	Appendix B: Soil Sampling.....	B-1
C	Appendix C: Plant Tissue Sampling	C-1
D	Appendix D: Winterization and Maintenance of Equipment	D-1
E	Appendix E: Example Land Application Permits.....	E-1

List of Figures

Figure 1-1. Typical composition of solids in raw wastewater (EPA 2004).....	1-3
Figure 1-2. The Nitrogen Cycle. (Source: http://msucares.com/crops/soils/images/nitrogen.gif)	1-8
Figure 2-1. Composition of a medium-textured mineral soil (Brady 1990).	2-2
Figure 2-2. A typical soil profile and its horizons (Brady 1990).	2-3
Figure 2-3. A visual representation of the comparative sizes and shapes of sand, silt, and clay particles (Hillel 1980).....	2-5
Figure 2-4. USDA textural triangle, showing the percentages of sand, silt and clay in the basic textural classes (USDA 2005).	2-6
Figure 2-5. Diagram for determining soil textural class by “feel.”	2-8
Figure 2-6. Various structural types found in mineral soils (Hillel 1980).	2-10
Figure 2-7. Cross sectional and plan view of various landscape positions (Daniels et al. 1984)...	2-14
Figure 2-8. Mineral and organic colloids with adsorbed ions (Brady 1990).	2-16
Figure 2-9. Volumes of water and air associated with 100 g of a silt loam soil at different moisture levels. The top bar shows the situation when a soil is completely saturated with moisture. This situation will usually occur for short periods of time during rain or irrigation. Water will soon drain out of the larger pores. The soil is then said to be at field capacity. Plants will remove moisture from the soil quite rapidly until they begin to wilt. When permanent wilting of the plants occurs, the soil moisture is said to be at the wilting point. There is still considerable moisture in the soil, but it is held too tightly to permit its absorption by plant roots (Brady 1990).....	2-19

TABLE OF CONTENTS

Figure 2-10. Illustration of relationship among soil components that provide nutrient cations for plants. (a) Soil solution nutrients, readily available to plant roots. (b) Adsorbed cations exchangeable with those in soil solution, moderately available. (c) Cations in structural framework of clays and organic colloids can move in time to the adsorbed state, slowly available. (d) Cations in rigid structural framework of minerals and organic tissue released only on weathering or decomposition, at best very slowly available. Most nutrient cations are in component (d), the least are in component (a) (Brady 1990).....	2-26
Figure 2-11. Relationships between pH on the one hand and the activity of microorganisms and nutrient availability on the other. The wide portions of the band indicate the zones of greatest microbial activity and the most ready availability of nutrients (Brady 1990).2-28	
Figure 2-12. Relationship between plant growth and concentration in the soil solution of elements that are essential to plants. Nutrients must be released (or added) to the soil solution in just the right amounts if normal plant growth is to occur (Brady 1990).....	2-30
Figure 3-1. The hydrologic cycle (Brady 1990).....	3-2
Figure 3-2. The water balance of a root zone (Hillel 1980).	3-3
Figure 3-3. Divisions of soil water.	3-6
Figure 3-4. Porous aquifer and perched water table above an impermeable layer (Brooks et al 2003).	3-7
Figure 3-5. Ground water characteristics and water table changes from wet to dry season (Brooks et al 2003).	3-7
Figure 3-6. Ground water mounding under treatment system (North Carolina 1989).....	3-8
Figure 3-7. Proper and Improper Locations for Groundwater Monitoring Wells. (Wells #1, 2 and 3 are improperly located; wells # 4, 5 and 6 are properly located.)	3-9
Figure 3-8. Proper and Improper Placement of Screens for Monitoring Wells.....	3-10
Figure 3-9. Construction Details for Ground Water Monitoring Well.	3-11
Figure 4-1. Typical hypochlorinator.....	4-4
Figure 4-2. Tablet chlorinator (WEF 1985).	4-4
Figure 4-3. Typical ultraviolet disinfection unit (WEF 1985a). Operation of Extended Aeration Package Plants.	4-6
Figure 5-1. Typical lagoon design. [From Wastewater Stabilization Ponds, 1981]	5-2
Figure 6-1. Motor, brake and water horsepower. [from Applied Math for Wastewater Plant Operators, 1991]	6-3
Figure 6-2. Pump characteristic curve (modified from Hauser 1991).	6-5
Figure 6-3. Schematic layout of a typical solid set irrigation system.	6-17
Figure 6-4. Typical spray head for a fixed system.	6-18
Figure 6-5. Hard hose traveler showing reel and gun cart.	6-19
Figure 6-6. Schematic layout of a hose-drag traveler. Travel lanes are 100 to 300 feet	6-20
Figure 6-7. Center pivot system.	6-21
Figure 6-8. Center pivot control panel.	6-22
Figure 7-1. Tensiometer method of determining soil-water content.	7-7
Figure 7-2. Electrical resistance block schematic (Hillel 1980).	7-8
Figure 7-3. Neutron probe schematic. [from The Nature and Properties of Soils]	7-9
Figure 7-4. Typical layout of a stationary sprinkler system. Sprinkler spacing is typically 50 to 65 percent of wetted diameter.....	7-21
Figure 9-1. Runoff from a wastewater land application site.....	9-4
Figure 9-2. Calculating Exchangeable Sodium Percentage.	9-9
Figure 9-3. Poor crop stand in a fescue pasture. The lighter areas indicate stunted or dying vegetation.....	9-12
Figure 9-4. Riparian buffer zones lining stream banks.	9-21
Figure 9-5. Sulfur deficiency in corn.	9-22

TABLE OF CONTENTS

Figure 9-6. Cross section of a French drain.	9-29
Figure 10-1. Acre with one inch of water = 27,154 gallons.	10-4
Figure 11-1. Absorption rates of chemicals through the skin of various parts of the body. Numbers are rates of absorption in comparison to the forearm.	11-9
Figure 11-2. Oxygen scale (Confined Spaces 1988).....	11-14

List of Tables

Table 2-1. Size and general characteristics of the three soil particle types.	2-5
Table 2-2. Essential macro- and micronutrients.	2-25
Table 2-3. Soil factors that may lead to deficiencies of selected nutrients.	2-29
Table 2-4. Key to Nutrient Disorders.	2-30
Table 4-1. Total Coliform Disinfection Requirements for Municipal Reclaimed Wastewater.	4-8
Table 7-1. Average Estimated Plant-Available Water for Various Soil Texture Classes.	7-4
Table 7-2. Recommended Wastewater Irrigation Volumes, as a Function of Soil Texture, Based on Estimates of Plant-Available Water Using the "Feel" Method.	7-5
Table 7-3. Average Reference Evapotranspiration from Vegetation Growing in Moist Soils.	7-12
Table 7-4. Seasonal crop-root zone development for specific growth stages.	7-14
Table 7-5. Percent of available soil water that may be used without causing yield or quality losses (Maximum Allowable Depletion or MAD)	7-14
Table 7-6. Use of the Checkbook Method for Irrigation Scheduling Soil-Moisture Balance Sheet 7-15	
Table 7-7. Approximate Water Infiltration Rates for Various Soil Textures and Slopes.	7-18
Table 7-8. Discharge characteristics for rotary impact sprinklers used with permanent stationary irrigation system.	7-19
Table 7-9. General flow rates and coverage diameter for big gun sprinklers.	7-20
Table 8-1. Situations in which the most recent mature leaf (MRML) is not the best indicator sample.	8-3
Table 8-2. Well Diameter Conversion Table.	8-10
Table 9-1. Salt tolerance of forage grasses and legumes 1/ 2/ [from National Range and Pasture Handbook].	9-11
Table 9-2. Nitrogen Fertilization Guidelines (Zublena et al. 1996).	9-13
Table 9-3. Nitrogen Rates and Timing of Effluent Application to Minimize Soil Leaching Losses and Luxury Consumption by Forage Plants (Green & Mueller 1996).	9-16
Table 11-1. Threshold quantities for chemicals requiring a process safety program or risk management program (all quantities are in pounds).	11-13

List of Equations

Equation 1-1. Calculation for weight of nonsettleable solids.	1-4
Equation 1-2. Calculation of maximum hydraulic loading rate.	1-12
Equation 4-1. Chlorine residual calculation.	4-2
Equation 6-1. Calculation of motor horsepower.	6-3
Equation 6-2. Calculation of brake horsepower.	6-3
Equation 6-3. Calculation of water horsepower.	6-3
Equation 7-1. Example calculation of Plant Available Water (PAW).	7-17
Equation 7-2. Calculation of Irrigation Water Requirement (IWR).	7-18
Equation 7-3. Calculation of irrigation rate for stationary sprinklers.	7-21
Equation 10-1. Converting mg/L to lbs/day.	10-2
Equation 10-2. Converting lbs/day to mg/L.	10-2

TABLE OF CONTENTS

Equation 10-3. Calculation of hydraulic loading rate.	10-4
Equation 10-4. Calculation of Irrigation Water Requirement (IWR).....	10-8
Equation 10-5. Calculation of non-growing season hydraulic loading rate.....	10-9
Equation 10-6. Calculation of Plant Available Nitrogen (PAN).	10-10
Equation 10-7. Simplified Calculation of Plant Available Nitrogen (PAN)	10-10
Equation 10-8. Calculation of Sodium Absorption Ratio.....	10-11
Equation 10-9. Calculation of milliequivalents.	10-11

Introduction

The goal of a wastewater land application (WLAP) system is to provide a method of wastewater treatment that protects the following:

- public health
- the environment
- waters of the state, including surface water and ground water

Land application systems are recognized by the State of Idaho Department of Environmental Quality (DEQ) and the U.S. Environmental Protection Agency (EPA) as beneficial wastewater re-use systems. Two benefits of using land application technology with wastewater are (1) eliminating the need for wastewater discharge into a surface water body and (2) providing wastewater as the primary source of irrigation water for nutrient utilization by crops that are grown and harvested on land application sites. Furthermore, a properly sited and operated wastewater land application system offers exceptional wastewater treatment and renovation as well as a source of aquifer recharge in some instances.

However, as with any wastewater treatment process, mismanagement can result in negative consequences. Over-application of wastewater to the land can result in runoff or leaching (downward movement of pollutants) and potential contamination of surface waters and/or ground water. Nutrients, metals, pathogens, salts, and other waste elements in the wastewater may cause environmental problems or health concerns if not properly managed.

Purpose of This Manual

The purpose of this manual is to provide operators of wastewater land application systems with the basic understanding needed to operate these systems in an efficient and environmentally sound manner. However, this manual is not intended to provide all required details for the complete evaluation and management of a wastewater land application system; there are many valuable reference materials that have been published on this subject, and these can provide more detailed information on the various topics discussed. Some of these materials are referenced in this manual; you are encouraged to consult additional resources as you continue to work as a wastewater land application operator.

This Manual and the Law

This manual presents material consistent with the laws, rules, and technical guidance for Idaho's wastewater land application program that existed at the time the manual was written. It is possible, indeed likely, that there will be changes in these laws and technical guidance, so it is important to stay up-to-date.

Although the organizations and government agencies involved in wastewater land application system operator certification will try to inform individuals who own and operate these systems of any changes, as they occur, you, ultimately, are responsible for ensuring that you are operating in compliance with current laws and rules.

If you have questions about wastewater land application systems, please contact the Idaho Department of Environmental Quality. If you have questions about becoming licensed or maintaining an existing license as either a wastewater treatment operator or as a wastewater land application operator, please contact the Idaho Bureau of Occupational Licenses.

How This Manual Was Developed

A committee of experts in the wastewater, regulatory, soils, agronomy, engineering, and associated fields developed the training materials for this manual. The manual is based on a list of topics and issues—referred to as *Needs-to-Know Criteria*—the committee determined each operator of a land application system must be knowledgeable about to perform the operator's job at a minimum level of competency. The manual and the associated training program explain and demonstrate each *Needs-to-Know Criteria*, such that, upon completion of the training, the operator should have the knowledge and the tools to effectively operate a wastewater land application system.

Updates to This Manual

This manual will be periodically updated to reflect changes in laws and technology. For example, interest in odor reduction from wastewater irrigation fields is increasing, thereby increasing the interest in using application equipment that distributes wastewater at or close to the ground surface. Distribution techniques, such as low-drop nozzles on center pivot equipment and drip irrigation systems, meet some of these needs in special cases, but this manual cannot cover every possible type of hardware that is used in the field.

The basics of wastewater treatment, distribution, and site operation and management are presented in some detail, as these are applicable to all sites. Special and unique systems may be only briefly mentioned; operators of such systems are encouraged to obtain more specific operation and maintenance information from the system manufacturer, designer, and/or installer.